

Impact of Processing on Retention of Beta Carotene of Sweet Potatoes

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The study was carried out to evaluate the impact of processing on retention of beta-carotene of sweet potatoes. Eight cultivars of sweet potatoes were used in the study; among which four cultivars were of orange-fleshed varieties viz. 'CIP 440012', 'CIP 440015', 'CIP 440267' & 'CIP 440021', and four cultivars were of white fleshed varieties viz. Lamatar White, Balewa Red, Sangachowk Red and Barbote White. The proximate composition and micronutrient composition of eight cultivars of raw sweet potatoes were determined. The carotene content of sweet potato cultivars was also calculated. Finally, the retention of carotene content in sweet potato cultivars under various processing methods (viz. boiling for 30 minutes at 100°C, baking in a microwave oven at 200°C for 30 minutes and drying in a cabinet dryer for 12 hours at 60°C) was observed. The orange fleshed varieties (CIP cultivars) had the greater proximate composition than the white fleshed varieties (local cultivars). The micronutrient composition of orange fleshed sweet potatoes and white fleshed varieties were similar. But the carotene content of the orange fleshed varieties was greater; ranging from 14.43-22.11 mg/100gm. The white fleshed varieties had a low carotene concentration of 0.70-1.83 mg/100gm. The retention of carotene content was observed higher in the boiling process (79%-89%) followed by baking (56%-78%) and least in drying (44%-67%). Also, the orange fleshed varieties had a better retention capability than white fleshed varieties in all the processing methods. Thus, orange fleshed sweet potatoes had a better nutrient profile with higher retention capabilities.

Key words: Micronutrient, Beta-carotene, Retention, Cultivars, Processing, Sweet Potato

Introduction

Sweet potato is a nutritious root crop that contains significant amount of fiber, beta-carotene and vitamin C, particularly in varieties with highly colored roots (Brandenberger *et al.*, 2014). In many developing countries, sweet potato is a secondary staple food and may play a role in controlling vitamin A deficiency as β -carotene rich orange-fleshed sweet potato is an excellent source of pro-vitamin A (Van Jaarsveldt *et al.*, 2005). Sweet potatoes are root vegetables that are under-utilized in most countries. They contain significant amount of powerful antioxidant, β -carotene. These types of vegetables are also rich in fiber, vitamin C and carbohydrates. β -carotene is a precursor of vitamin A. There are two basic types of sweet potatoes viz. orange fleshed sweet potato and white fleshed sweet potato. As the name suggests, orange-fleshed sweet potatoes are orange in color and white fleshed sweet potatoes are pale yellow colored. Sweet potato roots are good source of carbohydrates while sweet potato tops (leaves and stems) contain additional nutritional components in much higher concentrations than in many other commercial vegetables. They are rich in β carotene, vitamin B, iron, calcium, zinc and protein and the crop is more tolerant of diseases, pest and high moisture than many other leafy vegetables grown in the tropics (Islam., 2014).

In the present context of our country and in the whole world, vitamin A deficiency is still a huge concern. The study on β carotene content in sweet potatoes should lead to the generation of awareness about the consumption of sweet potatoes and its nutritious values among the people and also the quality analysis of sweet potato gives us the basic idea about its nutritional contents. Value addition in the more nutritionally significant sweet potatoes should result in further health benefits to the consumers and further profit to producers, breeders or farmers. Thus, Sweet potatoes (*Ipomoea batatas*) are selected as model food for this study.

The importance of this study is the generation of idea about the content of beta-carotene in different varieties of sweet potatoes, the effect of the different methods of processing on carotene content in the sweet potatoes and the knowledge about the proximate composition of the sweet potato. The main aim of this research is to assess the impact of processing on retention capabilities of beta-carotene after analysis of quality of various local and exotic varieties of sweet potatoes.

Materials and methods

Materials

Sweet potatoes were provided by Nepal Potato Research Program of Nepal Agricultural Research Council (NARC). The sweet potatoes were collected from the in-vivo cultivation field. The local varieties of sweet potatoes used were sourced from the farmers by NARC. Local varieties of sweet potatoes that were sampled are *Sangachowk Red*, *Balewa Red*, *Barbote White* and *Lamatar White*. These samples are classified under white fleshed sweet potatoes depending on the color of their flesh. The origin of *Sangachowk Red*, *Balewa Red*, *Barbote White* and *Lamatar White* are Sidhupalchowk district, Baglung, Illam and Lalitpur districts of Nepal respectively. The exotic varieties of sweet potatoes collected were orange fleshed sweet potatoes genotypes viz. 'CIP 440012', 'CIP 440015', 'CIP 440021' and 'CIP 440267'; which were sourced by NARC from CIP (International Potato Center), Peru. These varieties are orange fleshed sweet potatoes (OFSP). Altogether eight samples of sweet potato were used for analysis.

Methods

The analysis was carried out in the laboratory of Food Research Division, NARC and the laboratory at College of Applied Food and Dairy Technology. After collection of the samples was completed, the samples were washed properly and sweet potatoes free of mud, infestation, injuries,

Table 1

Proximate composition of sweet potato cultivars on dry basis

| Cultivars | Moisture | Protein | Crude fat | Crude fiber | Total ash | Carbohydrate |
|-----------------------|--------------|------------|------------|-------------|------------|--------------|
| 'CIP 440012' | 78.55± 0.29 | 6.32± 0.04 | 1.57± 0.03 | 1.88± 0.05 | 2.47± 0.02 | 87.76± 0.06 |
| 'CIP 440015' | 81.30± 0.25 | 1.50± 0.02 | 1.67± 0.04 | 4.06± 0.26 | 2.20± 0.02 | 90.56± 0.26 |
| 'CIP 440021' | 81.70 ± 0.02 | 6.20± 0.08 | 1.30± 0.04 | 2.55± 0.10 | 2.18± 0.04 | 87.78 ± 0.01 |
| 'CIP 440267' | 80.53 ± 0.22 | 3.37± 0.20 | 2.17± 0.06 | 2.03± 0.18 | 2.52± 0.03 | 89.92 ± 0.34 |
| <i>Sangachowk Red</i> | 57.42 ± 0.20 | 4.77± 0.05 | 0.51± 0.07 | 0.60± 0.01 | 2.20± 0.01 | 91.92 ± 0.11 |
| <i>Balewa Red</i> | 66.13 ± 0.41 | 4.72± 0.03 | 1.39± 0.03 | 0.83± 0.05 | 2.05± 0.05 | 91.02 ± 0.12 |
| <i>Barbote White</i> | 63.72 ± 1.37 | 3.04± 0.01 | 0.88± 0.03 | 0.79± 0.02 | 2.22± 0.02 | 93.08 ± 0.03 |
| <i>Lamatar White</i> | 74.04 ± 0.41 | 3.71± 0.06 | 1.30± 0.01 | 3.54± 0.09 | 2.15± 0.03 | 89.30 ± 0.13 |

The values are the mean of triplicate and the values with ± indicate standard deviation.

blemished and sprouts were chosen for further analysis. The retention of the carotene content in the sweet samples was determined. Carotene content in the sweet potato after undergoing heat treatment process such as boiling and baking was estimated. Baking process was carried out a temperature of 200°C for 30 minutes in a microwave oven. Boiling was done for 30 minutes at 100°C to determine the retention abilities of sweet potatoes in terms of their carotene content. Also, the carotene content of dried and milled sweet potato powder was also determined to review the effects of drying and milling on carotene content of the sweet potato. Sweet potato samples were dried at cabinet drier for 12 hours at 60°C and milled using a grinder. The powder was then used for the determination of carotene content. Fresh sweet potato samples were used to determine the proximate and ultimate content of sweet potatoes. It was then peeled, sliced (1/4 inch thick) and dried at 60°C for 12 hours in cabinet drier. The dried sample was picked in polyethylene bags for further analysis.

Carotene content was determined according to the method described by AOAC, 1980. The moisture content, ash content, protein content, crude fat, crude fibre, calcium content, iron, phosphorus, vitamin C content of sweet potato was determined using the analysis methods according to AOAC, 1980. The triplicate samples were analyzed for each parameter.

Table 2

Micronutrient composition of sweet potato cultivars

| Sample | Iron content | Phosphorus content | Calcium content | Vitamin C |
|-----------------------|--------------|--------------------|-----------------|--------------|
| CIP 440012 | 1.63 ± 0.11 | 27.72 ± 0.96 | 17.27 ± 0.46 | 23.21 ± 0.21 |
| CIP 440015 | 0.76 ± 0.23 | 28.09 ± 0.69 | 17.70 ± 0.40 | 21.41 ± 0.09 |
| CIP 440267 | 1.53 ± 0.13 | 26.37 ± 1.42 | 17.88 ± 0.61 | 19.39 ± 0.51 |
| CIP 440021 | 1.34 ± 0.21 | 21.40 ± 0.61 | 18.18 ± 0.52 | 24.10 ± 0.20 |
| <i>Lamatar White</i> | 4.17 ± 0.30 | 22.54 ± 0.12 | 31.54 ± 0.31 | 26.56 ± 0.21 |
| <i>Balewa Red</i> | 7.16 ± 0.27 | 18.96 ± 0.40 | 31.01 ± 0.28 | 26.80 ± 0.98 |
| <i>Sangachowk Red</i> | 3.39 ± 0.22 | 21.40 ± 1.27 | 35.97 ± 0.11 | 25.63 ± 0.20 |
| <i>Barbote White</i> | 5.06 ± 0.10 | 18.81 ± 0.08 | 34.05 ± 0.32 | 26.09 ± 0.17 |

The values are the mean of triplicate and the values with ± indicate standard deviation).The values are in dry basis and represented as in mg/100 gm.

Data analysis

The data thus obtained from different analysis were statistically analyzed by using the statistical program SPSS. The analysis of variance (ANOVA) at 5% level of significance was used for the analysis and interpretations were observed as Least Significant Difference, mean value and standard error of means and Coefficient of Variance (%).

Results and Discussions

The physicochemical analysis of multiple varieties of sweet potatoes that includes parameters such as proximate constituents (moisture, total ash, protein, crude fat, crude fiber and carbohydrate), minerals (iron, calcium, and phosphorus), Vitamin C and carotene content are shown in the tables below. The retention of carotene under various heat treatment processes was also observed and reported below.

Proximate composition

The proximate composition of sweet potato cultivars is described in Table 1. CIP 440012 has the highest protein content while CIP 440015 has the highest crude fiber content. The proximate analysis was determined in order to qualitatively observe the nutritional properties of sweet potato cultivars and compare the differences among white flesh and orange-fleshed varieties.

Hence, the proximate composition of the orange-fleshed potatoes (CIP cultivars) and white fleshed sweet potatoes (which were the four local varieties used in the study) was determined and tabled as above.. The comparative evaluation of the proximate composition of sweet potato between the orange fleshed and white fleshed varieties (CIP varieties and local varieties respectively) shows that OFSP have higher fat, protein, fiber and moisture content than white fleshed varieties and lower carbohydrate content.

Micronutrient composition

The micronutrient compositions of sweet potato cultivars are described in Table 2. *Balewa* Red has the highest Vitamin C content and highest iron content while CIP 440015 has the highest phosphorus content. *Sangachowk* Red has the highest calcium content. According to Quality and Nutrition Lab, CIP, the average micronutrient content of orange-fleshed sweet potato should be as: iron- 0.5 mg, calcium- 34 mg, phosphorus- 29 mg per 100 grams of fresh-weight, unpeeled sweet potato. Four CIP varieties used are orange fleshed sweet potato. So, the iron content ranges from 0.76-1.63 mg/100gm. Similarly, the phosphorus content ranges from 21.40-28.09 mg/100 gm. In addition, the calcium content ranges from 17.27-18.18 mg/100 gm. The calcium content is calculated higher than the average data while the iron content is calculated lower and the phosphorus value holds true. This difference in values to the data obtained from CIP may be due to the peeling of sweet potatoes for the study. The iron content of white fleshed varieties (local varieties) ranges from 3.39-7.76 mg/100gm. This value is much greater compared than the orange fleshed varieties. Similarly, the calcium content is also higher than OFSP ranging from 31.01-35.97 mg/100gm. But, the phosphorus content is less than OFSP ranging from 18.81-22.54 mg/100 gm. The vitamin C content of OFSP (CIP varieties) ranged from 19.31-21.40 mg/100 gm which is slightly less than white fleshed sweet potatoes; ranging 25.63-26.80 mg/100gm.

Carotene content

The beta-carotene content of sweet potato cultivars are described in Table 3. CIP 440021 has the highest beta-carotene content. CIP varieties of sweet potatoes had a higher beta-carotene content compared to local varieties of sweet potatoes.

Table 3

Beta-carotene content of sweet potato cultivars

| Sample | Beta-carotene content (mg/100gm) |
|----------------|----------------------------------|
| CIP 440012 | 14.43 ± 0.46 |
| CIP 440015 | 18.38 ± 0.58 |
| CIP 440267 | 19.35 ± 0.55 |
| CIP 440021 | 22.11 ± 0.36 |
| Lamatar White | 1.83 ± 0.11 |
| Balewa Red | 0.90 ± 0.05 |
| Sangachowk Red | 0.85 ± 0.05 |
| Barbote White | 0.70 ± 0.08 |

The values are the mean of triplicate and the values with ± indicate standard deviation) The values are interpreted to total carotenoids as beta-carotene.

From the analysis, it was found that the orange-fleshed sweet potatoes have a much higher carotene content compared to white fleshed sweet potatoes. The carotene content of orange fleshed (CIP varieties) ranged from 14.43-22.11 mg/100gm while the carotene content of white fleshed varieties (local varieties) ranged from 0.70-1.83 mg/100 gm.

From the analysis, it was found that the orange fleshed sweet potatoes have a much higher carotene content compared to white fleshed sweet potatoes. The carotene content of orange fleshed (CIP varieties) ranged from 14.43-22.11 mg/100gm while the carotene content of white fleshed varieties (local varieties) ranged from 0.70-1.83 mg/100 gm. According to Quality and Nutrition Lab, CIP, the total carotenoids and beta-carotene of orange fleshed sweet potato is 15.5 mg and 13.1 mg respectively per 100 grams of fresh-weight, raw, unpeeled sweet potato. Due to lack of HPLC process, the beta-carotene was not separated from total carotene in the study. But as majority of the carotenes is beta-carotene in any fruits and vegetables, the carotene content determined was expressed as beta-carotene. Comparing the values calculated from the analysis with the data obtained from CIP, the values hold true. The white fleshed variety had a low carotene concentration. It is due to the absence of color pigments that provide the OFSP its orange and in some cases, purple color. CIP 440021 had the highest carotene concentration of 22.11 mg/100gm. Barbote White had the lowest carotene concentration of 0.70 mg/100gm.

Retention of carotene content in sweet potato cultivars:

The effects of various processing methods on beta-carotene content of CIP cultivars are reported in Table 4. The highest percentage of carotene retention was observed at 89% in CIP 440015 and CIP 440021 after boiling. The lowest percentage of carotene retention was seen at 64% in dried CIP 440015 and CIP 4400267 cultivars.

The orange-fleshed sweet potato varieties included in this study showed different intensities of dark-orange flesh color. The flesh color of the root was directly associated with the Beta--carotene content. Similar results were reported by Simonne *et.al.*(1993) and Kidmose *et.al.*,(2007). Results indicated that the orange-fleshed varieties varied significantly in their carotenoid content and retention capabilities. In the CIP cultivars (orange fleshed sweet potato), highest retention of the carotenes (79%-89%) was observed in the boiling process followed by baking (56%-78%). In the drying (cabinet) method, the least percentage of carotene retention was 44%-67%. The effects of various processing methods on beta-carotene content of local cultivars are reported in Table 5. The highest percentage of carotene retention in local cultivars was observed at 83% in Barbote White.

Local varieties had low carotene content than CIP cultivars and the retention capability was lower compared to CIP cultivars. In the local cultivars (white fleshed sweet potato), the highest retention of carotenes, similar to CIP cultivars but at a lower percentage, was observed in boiling process at 79%-84% which was followed by baking process at 57%-67%. The least percentage of carotene retention in local clones was observed in drying samples at 44%-56%.

Table 4

Effects of various processing methods on carotene content of CIP cultivars

| Varieties | Processing conditions | Carotene content | Retention (%) |
|------------|-----------------------|------------------|---------------|
| CIP 440012 | Raw | 14.43 ± 0.46 | 100 |
| | Boiling | 12.34 ± 0.42 | 85 |
| | Baking | 11.16 ± 0.35 | 77 |
| | Drying | 9.68 ± 0.18 | 67 |
| CIP 440015 | Raw | 18.38 ± 0.58 | 100 |
| | Boiling | 16.38 ± 0.55 | 89 |
| | Baking | 14.37 ± 0.37 | 78 |
| | Drying | 11.78 ± 0.58 | 64 |
| CIP 440267 | Raw | 19.35 ± 0.55 | 100 |
| | Boiling | 16.69 ± 0.55 | 86 |
| | Baking | 14.31 ± 0.30 | 74 |
| | Drying | 12.38 ± 0.33 | 64 |
| CIP 440021 | Raw | 22.11 ± 0.36 | 100 |
| | Boiling | 19.67 ± 0.46 | 89 |
| | Baking | 17.37 ± 0.55 | 79 |
| | Drying | 14.28 ± 0.46 | 65 |

The values are the mean of triplicate and the values with ± indicate standard deviation) (The carotene content is expressed in mg/100gm and interpreted as beta--carotene.

Variation in the retention of carotenoids may be due to difference in enzymatic oxidation during processing. This was also in the agreement with the study by Ameny and Wilson (1997). The influence of different processing procedures on the carotene content of orange fleshed roots have been reported in sweet potato (Huang *et al.*, 1999), carrots (Dutta *et al.*, 2005), and cassava (Chavez *et al.*, 2007). More than 100% retention of carotenoids was reported in spinach and winged bean through steam and water blanching (Dietz *et al.*, 1988). No loss of beta--carotene in chopped or grated raw sweet potato was observed by Van Jaarsveld *et al.*, 2006. This showed that there was no or little enzymatic oxidation in cut fresh samples which accounted for the 100% retention. In all other procedures, occurrence of less retention values could be due to leaching of vitamin A precursor as in drying or thermo-chemical reactions occurring during cooking times (Chandler and Schwartz 1988). Moreover, variation in processing is also affected by slice thickness of pieces, duration of baking and stage of maturity (Demasse *et al.*, 2007). According to Bradbury and Holloway (1988), different varieties have different cooking time due to inherent variations in starch content, composition as well as the level

of soluble fibers. High retention of alpha and beta-carotene during processing and storage could be attributed to the facts that cooking makes it easy for the complete elution of beta-carotene in processed foods than in fresh. In methods like boiling and baking, the low retention may be due to the dripping off pigments and in drying, it can be due to thermo-chemical reactions and leaching of the pigments.

Table 5

Effects of various processing methods on carotene content of local cultivars

| Varieties | Processing conditions | Carotene content | Retention (%) |
|--------------------------|-----------------------|------------------|---------------|
| <i>Lamatar</i> White | Raw | 1.83 ± 0.11 | 100 |
| | Boiling | 1.45 ± 0.05 | 79 |
| | Baking | 1.22 ± 0.05 | 67 |
| | Drying | 1.02 ± 0.03 | 56 |
| <i>Balewa</i> Red | Raw | 0.90 ± 0.05 | 100 |
| | Boiling | 0.74 ± 0.05 | 82 |
| | Baking | 0.58 ± 0.09 | 65 |
| | Drying | 0.41 ± 0.06 | 46 |
| <i>Sangachowk</i> Red | Raw | 0.85 ± 0.05 | 100 |
| | Boiling | 0.71 ± 0.06 | 84 |
| | Baking | 0.54 ± 0.05 | 64 |
| | Drying | 0.44 ± 0.05 | 51 |
| <i>Barbote</i> White | Raw | 0.70 ± 0.08 | 100 |
| | Boiling | 0.58 ± 0.03 | 83 |
| | Baking | 0.40 ± 0.01 | 57 |
| | Drying | 0.31 ± 0.02 | 44 |

The values are the mean of triplicate and the values with ± indicate standard deviation. The carotene content is expressed in mg/100gm and interpreted as beta--carotene.

In the study, the highest retention of carotenoids was found in the boiling process; it is a common method of process for human consumption and it can be beneficial for the production of value added sweet potato products. The study showed that the orange fleshed varieties possessed higher carotene content in the fresh as well as in the different processing methods compared to white fleshed varieties. Chandler and Schwartz (1988) had reported that carotene deficient varieties are more susceptible to degradation than carotene rich ones. This is in agreement with the study which reports that white fleshed varieties have low carotene content and hence also possess lower retention capability. Effects of various traditional processing methods on carotene content of sweet potato have been reported by Bengtsson *et al.*, (2008), K'osambo *et al.*, (1998), Hagenimana *et al.*, (1999) etc. Bengtsson *et al.*, (2008) had observed low retention values to the fresh unprocessed samples while K'osambo *et al.*, (1998) could find decreased carotene content in boiled samples. A loss of 20%-30% was observed by Hagenimana *et al.*, (1999) in CIP cultivars subjected to boiling as well as drying into chips compared to initial carotenoid amount in fresh storage roots.

Retention of carotenoids after boiling is more important since majority of common people consume sweet potato roots after boiling. The people who were traditionally dependent on the consumption of white fleshed local cultivars are unaware of the nutritive value of orange fleshed sweet potato as most of the varieties selected by the consumers are based on the best

taste, flavor and texture rather than those having a better nutrient profile (Chattopadhyay *et al.*, 2005). The moderate amounts of beta carotene present in the dried process may be useful for the production of sweet potato flour and orange colored crispy chips. The high carotenoids retention in the different processing methods indicates the possibility of significantly improving the nutritive value by making more acceptable products to the consumers. The retention of carotenoids in different processing methods helps to validate the techniques for obtaining food products of higher nutritional quality.

Conclusions

Micronutrient content of white fleshed sweet potatoes are found in greater concentration as compared to orange-fleshed sweet potato varieties. Local varieties have higher micronutrient concentration than CIP varieties. Orange fleshed sweet potato varieties have higher carotene content than white fleshed varieties. Local varieties of sweet potato have low carotene content compared to CIP varieties of sweet potatoes. Based on the results obtained from the study, the high retention of beta-carotene was obtained during boiling for 30 minutes at 100°C followed by baking at 200°C for 30 minutes and finally by drying (cabinet drying at 60°C for 12 hours followed by grinding into powder). Sweet potatoes have a superior carotenoid content in comparison to other fruits, vegetables and tubers. Breeders can use these results for further selection of promising cultivars of sweet potato.

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